there are signs of the place becoming very popular, more than 1100 visitors having been admitted on a single day. The magnificent colours of many of the fish, in particular, form a most attractive display. The exhibits include sea-snakes (Enhydrina and species of Distira), and among the fish species of the following:—Ginglymostoma, Stegostoma, Chiloscyllium, Muræna, Arius, Therapon, Serranus, Lutjanus, Myripristis, Trachynotus, Pterois, Caranx, Antennarius, Heniochus, Julis, Teuthis, Balistes, Tetrodon. The invertebrates comprise cuttle-fish, holothurians, hermit-crabs (Clibanarius, &c.), swimming-crabs (Scylla and Neptunus), lobsters (Panulirus), prawns (Penæus), &c. All the specimens have been taken on the Madras coast within a few miles of the aquarium.

INDIAN MUSEUM PUBLICATIONS.

According to the report for 1908–9, the organisation of the Indian Museum has been in need of reform, and the views of the trustees in this respect are shared by the Government of India. The trustees have accordingly "accepted the Government of India's proposals as regards fresh legislation whereby a re-organisation of the museum may be effected. The two main principles that they have had before them in the suggestions they have made to the Government as regards this new legislation have been (1) that each section of the museum should be under proper expert management, and (2) that the heads of the different sections should be *ex officio* trustees themselves. They believe that the new Act which it is proposed to introduce shortly, and of which they have received a draft, will enable them to give effect to these principles.

"The trustees have also to express their gratitude to the Government of India for the support given them in their proposals regarding an increase in the scientific staff and in the pay of the superintendent of the natural history section. They are of the opinion that the alterations sanctioned in these respects will not only enable them to retain the services of their officers in a way that has not proved possible in the past, but will also increase the utility of the museum in many directions. . . . They note with satisfaction the increase, not only in the collections, but also in the scope of the scientific work accomplished by these means; but they are convinced that only a permanent re-organisation of the staff such as has now been rendered possible will enable the museum to maintain and expand its work as a centre of zoological work both purely scientific and directly practical."

No. 3 of the second volume of "Memoirs of the Indian Museum" is devoted to a description, by Dr. R. E. Lloyd, of the deep-sea fish caught by the R.I.M.S. ship *Investigator* during the present century. Colonel Alcock's catalogue of the deep-sea fish taken by the same vessel during last century was published ten years ago, and the present memoir includes notices of such forms as have been named since that date, together with the descriptions of five new genera and species. Four of the new genera appear to be nearly allied to previously known types, but the small, tadpole-like *Liparoides beauchampi* differs from other deep-sea Cyclopteridæ (misprinted Clycopteridæ in the memoir) by the possession of a diphycercal tail and small pelvic fins not fused into a sucker. The memoir concludes with a notice of supposed evidence of mutation in a small pediculate fish of the genus Malthopsis from the Andamans. These fishes were taken from four separate but not very distant stations in the Andamanese Sea, where they appear to form distinct communities; they include five types differing from one another in the relative breadth of the disc and the form and arrangement of the dermal ossicles. These differences can scarcely, however, be regarded as of specific value, while as two or more types occur at each station they obviously do not indicate local races.

The trustees have sanctioned the publication of an annotated list of the Asiatic beetles in the collection of the Indian Museum, under the editorship of the superintendent of the natural history section, of which the first part, dealing with the tiger-beetles (Cicindelinæ), has been issued. The text is in somewhat small type, and it is unfortunate that the specific names are printed in italics similar to those used for the publication-references. Moreover, the references are not free from misprints, as witness *Deutshe* on p. 9, while to others than specialists such references as *Jahrb.* (p. 10) and "*Ent.*" (p. 12) are meaningless.

The third part of vol. iii. of "Records of the Indian Museum" contains a large number of papers dealing mainly with invertebrates, and especially insects. Dr. Annandale has, however, a note on lizards from Travancore, in which reference is made to colour-changes in *Charasia blanfordiana*, a relative of the well-known *Calotes versicolor*. The lizards of this genus appear to take the place in India occupied in the Himalaya, and Asia and Europe generally, by Agama. The colour-changes do not seem always for the purpose of concealment, as the author has seen a specimen temporarily pale in colour basking on a red mud-wall, and a second in full sunshine on a black rock. Other specimens, on the contrary, in similar situations, were more in harmony with their surroundings in the matter of colouring.

MENDELEEFF'S LIFE AND WORK.[1]

To many of the present generation of English chemists the commanding, patriarchal figure of Mendeléeff was quite familiar. Though his several visits to London were often connected with official business of the Russian Government Department of Weights and Measures, of which he was the chief official during the later years of his life, he came several times with more purely scientific objects. In 1889 the occasion of his presence in London was the Faraday lecture, which he had been invited to give to the Chemical Society, but which, owing to a sudden and urgent recall to his home, he was unable to deliver in person. His last appearance in this country was in November, 1905, when the Copley medal was awarded to him by the Royal Society.

The Chemical Society can see his face no more, and all that it can now do is to inscribe high on its roll of honour the name which, more than any other, will be for ever associated with the development of the great generalisation known as the periodic system of the elements.

Dmitri Ivanovitsch Mendeléeff[2] was the fourteenth and youngest child of his parents, Ivan Pavlovitsch and Maria Dmitrievna, *née* Kornileff. His father, a former student of the Chief Pedagogic Institute of St. Petersburg, obtained the appointment of director of the gymnasium at Tobolsk, in Siberia, where he met Maria Dmitrievna, who became his wife. After a few years at Tobolsk he was transferred to school directorships in Russia, first at Tambov and afterwards at Saratov; but in order to satisfy the ardent wish of his wife, he took advantage of an opportunity of exchange, by which he became once more director of the college at Tobolsk, and the family returned to Siberia. Here on January 27, 1834 (O.S.) was born Dmitri Ivanovitsch, the youngest son. Soon after his birth the father became gradually blind from cataract in both eyes, and was obliged to resign, the whole family, including eight children, having to subsist on a small pension of 1000 roubles (about 100*l.* per annum). The mother, Maria Dmitrievna, belonged to the old Russian family Kornileff, settled at Tobolsk. They were the first to establish in Siberia the manufacture of paper and glass. In 1787 the grandfather of Dmitri opened at Tobolsk the first printing press, and from 1789 produced the first newspaper in Siberia, the *Irtysch*. The glass works were situated in the village of Aremziansk, a short distance from Tobolsk.

There can be no doubt the mother was a woman possessed of remarkable vigour of mind, who exercised great influence over her children. Her activity and capacity are further illustrated by the fact that when her husband became blind she revived the business of the glass works, and carried it on until after his death from consumption in 1847.

1 The Mendeléeff Memorial Lecture delivered before the Chemical Society on October 21, 1909, by Sir William A. Tilden, F.R.S. Abridged from the Journal of the Society for December, 1909.

2 For many of the details of Mendeléeff's career and of his home life the writer is indebted to the family chronicle compiled, soon after his death, by his niece, N. J. Gubkina (*née* Kapustina), and published in St. Petersburg, also to pamphlets by A. Archangelsky and P. J. Robinowitsch. He also desires to express his thanks to Mr. D. V. Téquier, of St. Petersburg, as well as to several Russian friends, for valuable assistance in translation.

Tobolsk was at that time a place of banishment for many political exiles, the so-called Decembrists, one of whom, Bassargin, married Olga, an elder sister of Dmitri. To these Decembrists the boy owed his first interest in natural science. His mother had always cherished the hope that at least one of her children would devote himself to science, and accordingly, after her husband's death and the destruction of the glass works by fire, and spite of failing health and scanty means, she undertook the long and tedious journey from Tobolsk to Moscow, accompanied by her remaining children, Elizabeth and Dmitri Ivanovitsch, with the object of entering the latter, then nearly fifteen years of age, at the university. Disappointed in this object, owing to official difficulties, she removed in the spring of 1850 to St. Petersburg, where ultimately, with the assistance of the director, Pletnoff, of the Central Pedagogic Institute, a friend of her late husband, she succeeded in securing for her son admission to the physico-mathematical faculty of the institute, together with much-needed pecuniary assistance from the Government.

The debt which Dmitri Ivanovitsch owed to his mother he acknowledged later in the introduction to his work on "Solutions," which he dedicated to her memory.

In the Pedagogic Institute Dmitri Ivanovitsch was thus able to devote himself to the mathematical and physical sciences under the guidance of Profs. Leng and Kupfer in physics, Woskresensky in chemistry, and Ostragradsky in mathematics. Unfortunately, at the end of his course his health failed, and about this time his mother died. Having been ordered to the south, he fortunately obtained an appointment as chief science master at Simferopol, in the Crimea. The southern climate soon alleviated the serious symptoms of lung disorder, and removal being necessary in consequence of the Crimean War, he was able soon afterwards to undertake a post as teacher of mathematics and physics at the gymnasium at Odessa. In 1856 he returned to St. Petersburg, and at the early age of twenty-two was appointed privat-docent in the University, having secured his certificate as master in chemistry.

At this time he appears to have passed rapidly from one subject to another, but he soon found matter for serious and protracted study in the physical properties of liquids, especially in their expansion by heat; and when, in 1859, by permission of the Minister of Public Instruction, Mendeléeff proceeded to study under Regnault in Paris and afterwards in Heidelberg, he devoted himself to this work, communicating his results to Liebig's *Annalen* and the French Academy of Sciences. Returning two years later to St. Petersburg, he secured his doctorate, and was soon afterwards appointed professor of chemistry in the Technological Institute. In 1866 he became professor of general chemistry in the University, Butlerow at the same time occupying the chair of organic chemistry.

As a teacher, Mendeléeff seems to have possessed a special talent for rousing a desire for knowledge, and his lecture-room was often filled with students from all faculties of the University. Many of his former students remember gratefully the influence he exercised over them.

One of Mendeléeff's most remarkable personal features was his flowing abundance of hair. The story goes that, before he was presented to the late Emperor, Alexander III., his Majesty was curious to know whether the professor would have his hair cut. This, however, was not done, and he appeared at Court without passing under the hands of the barber. His habit was to cut his hair once a year, in spring, before the warm weather set in. His eyes, though rather deep-set, were bright blue, and to the end of his life retained their penetrating glance. Tall in stature, though with slightly stooping shoulders, his hands noticeable for their fine form and expressive gestures, the whole figure proclaimed the grand Russian of the province of Tver.

At home, Mendeléeff always wore an easy garment of his own design, something like a Norfolk jacket without a belt, of dark grey cloth. He rarely wore uniform or evening coat, and attached no importance to ribbons and decorations, of which he had many.

As to his views on social and political questions, many people thought him a rigid monarchist, but he said of himself that he was an evolutionist of peaceable type, desiring a new religion, of which the characteristic should be subordination of the individual to the general good. He always viewed with much sympathy what is called the feminine question. At the Office of Weights and Measures he employed several ladies, and about 1870 he gave lectures on chemistry to classes of ladies.

Mendeléeff held decided views on the subject of education, which he set forth in several publications, especially "Remarks on Public Instruction in Russia" (1901). Here he says:—"The fundamental direction of Russian education should be living and real, not based on dead languages, grammatical rules, and dialectical discussions, which, without experimental control, bring self-deceit, illusion, presumption, and selfishness." Believing in the soothing effect of a vital realism in schools, he considered that universal peace and the brotherhood of nations could only be brought about by the operation of this principle. Speaking of the reforms desirable, he says that "for such reforms are required many strong realists; classicists are only fit to be landowners, capitalists, civil servants, men of letters critics, describing and discussing, but helping only indirectly the cause of popular needs. We could live at the present day without a Plato, but a double number of Newtons is required to discover the secrets of nature, and to bring life into harmony with the laws of nature." Mendeléeff was evidently a philosopher of the same type as our own Francis Bacon.

In 1863, when twenty-nine years of age, Mendeléeff married his first wife, *née* Lestshoff, by whom he had one son, Vladimir,[1] and a daughter, Olga; but the marriage proved unhappy, and after living apart for some time there was a divorce. In 1881 he married a young lady artist, Anna Ivanovna Popova, of Cossack origin, and lived first at the University and afterwards in the apartments built for the director at the Bureau of Weights and Measures. Here his younger children were born, Lioubov (Aimée), Ivan (Jean), and the twins, Maria and Vassili (Basile).

In 1890, in consequence of a difference with the administration, Mendeléeff retired from the professorship in the University. During the disturbances among the students in that year, he succeeded in pacifying them by promising to present their petition to the Minister of Education. Instead of thanks for this service, however, the professor received a sharp reprimand from the authorities for not minding his own business. The consequence was that Mendeléeff resigned. Independently of the petition, however, there were probably deeper reasons for his being out of favour with the Ministry, connected with his irreconcilable enmity to the classical system of education already referred to. Of this he had made no secret, and it had already brought him into conflict with the authorities. In 1893, however, he was appointed by M. Witte to the office of director of the Bureau of Weights and Measures, which he retained until his death.

Such are the chief features of a great personality. If it be admitted that stories are told of his occasional irritability of temper, we can well place on the other side of the account the cordial relations always subsisting between the professor and his assistants, the confidence and respect between the master and his servants, the deep affection between the father and his children, which are known to have persisted throughout his life, and which could be illustrated by many anecdotes. These stories merely serve "to give the world assurance of a man."

For us who live on the other side of Europe, separated as we are by race, by language, by national and social customs, and by form of government, it is not easy to understand completely the texture of such a mind, the quality of such genius, and the conditions, social or political, which may have served to encourage or to repress its activity. The Russian language may be eloquent, expressive, versatile, and harmonious, or it may possess any other good quality that may be claimed for it by those to whom it is a mother tongue; but the fact remains that it is a barrier to free intercourse between the Russian people and the world outside the Russian Empire. This alone creates a condition which must influence the development of thought, and must give to Russian science and philosophy a colour of its own. Mendeléeff was, like many educated Russians, a man of very liberal views on such

[1] Died in 1899, aged thirty-four.

subjects as education, the position of women, on art and science, and probably on national government. We can hardly guess what would be the influence on such a nature of a rigid administrative *régime* which forbids even the discussion of such questions. We in England are almost unable to imagine such a state of things as would be represented by the closing of, say, University College for a year or more, because the question whether the House of Lords ought to be abolished had been debated in the Students' Union. Imagine the professor of chemistry, along with his colleagues, for such a reason deprived of the use of his laboratory by the police, and only allowed to resume his studies when someone down at Scotland Yard thought proper. Such being the experience of most of the Russian universities and technical high schools, it is not surprising that the output of Russian science, notwithstanding the acknowledged genius of the Russian people, appears sometimes comparatively small. The amount of work done by Mendeléeff, both experimental and theoretical, was prodigious, and all the more remarkable considering the cloudy atmosphere under which so much of it was accomplished.[1]

In 1882 the Royal Society conferred on Mendeléeff, jointly with Lothar Meyer, the Davy medal. In 1883 the Chemical Society elected him an honorary member, and in 1889 it conferred upon him the highest distinction in its power to award, namely, the Faraday lectureship, with which is associated the Faraday medal. In 1890 he was elected a Foreign Member of the Royal Society, and in 1905 he received the Copley medal. So far as England is concerned, his services to science received full acknowledgment. It is all the more remarkable, therefore, that he never became a member of the Imperial Academy of Sciences of St. Petersburg.

Towards the end of 1906 Mendeléeff's health began to fail. Nevertheless he was able to attend the Minister on the occasion of an official visit in January to the office of Weights and Measures, but he caught cold and, enfeebled as he had been by influenza in the preceding autumn, inflammation of the lungs set in. Retaining consciousness almost to the last, he requested even on the day of his death to be read to from the "Journey to the North Pole," by his favourite author, Jules Verne. He died in the early morning of January 20 (O.S.), 1907, within a few days of his seventy-third birthday. He was buried in the Wolkowo Cemetery beside the graves of his mother and son.

Turning now to a survey of Mendeléeff's work as a man of science, it will be sufficient if we pass lightly over his first essays. Like so many other chemists, he began by handling simple questions of fact, his first paper, dated 1854, when he was twenty years of age, being on the composition of certain specimens of orthite. It was not until 1859 that he settled down to serious examination of the physical properties of liquids, which led him to a long series of experiments on the thermal dilatation of liquids, of which the chief ultimate outcome was the establishment of a simple expression for the expansion of liquids between 0° and the boiling point. This formula is liable to the same kind of modification which has been found necessary in the case of gases. It is, of course, applicable only to an ideal liquid from which all known liquids differ by reason of differences of chemical constitution and consequent differences of density, viscosity, and other properties.

Mendeléeff devoted a large amount of time and of experimental skill to the estimation of the densities of various solutions, especially mixtures of alcohol and water and of sulphuric acid and water, and of aqueous solutions of a large number of salts. In 1889 he embodied the whole in the monograph already referred to. In a paper communicated to the Transactions in 1887 (li., 779), he stated his views in the following words:—"Solutions may be regarded as strictly definite atomic chemical combinations at temperatures higher than their dissociation temperatures. Definite chemical substances may be either formed or decomposed at temperatures which are higher than those at which dissociation commences; the same phenomenon occurs in solutions; at ordinary temperatures they can be either formed or decomposed." These views, however, did not prevent his recognising van 't Hoff's gas theory as applicable to dilute solutions.

In conjunction with some of his students, Mendeléeff also studied minutely the question of the elasticity of gases, and published several papers on the subject (see Royal Society Catalogue), extending over a period of some ten years from 1872.

Another subject to which Mendeléeff gave a good deal of attention was the nature and origin of petroleum. Having already reported in 1866 on the naphtha springs in the Caucasus, in the summer of 1876 he crossed the Atlantic and surveyed the oil fields of Pennsylvania. In the course of these investigations, he was led to form a new theory of the mode of production of these natural deposits. The assumption that the oil is a product of the decomposition of organic remains he rejects on a variety of grounds, which are set forth in a communication to the Russian Chemical Society (Abstract, see *Ber.*, 1877, x., 229). Mendeléeff assumes, as others have done, that the interior of the earth consists largely of carbides of metals, especially iron, and that hydrocarbons result from the penetration of water into contact with these compounds, metallic oxide being formed simultaneously. The hydrocarbons are supposed to be driven in vapour from the lower strata, where temperature is high, to more superficial strata, where they condense and are retained under pressure. In 1886, in consequence of rumours as to the possible exhaustion of the Russian oil fields, he was sent by the Government to Baku to collect information, and in 1889 he made a communication on this subject to Dr. Ludwig Mond, which is printed in the Journal of the Society of Chemical Industry (1889, viii., 753).

The influence of the great generalisation known as the periodic law can best be estimated by reviewing the state of knowledge and opinion before the announcement and acceptance of the principle by the chemical world, and subsequently glancing at the influence which, directly or indirectly, it has produced on scientific thought, not only in regard to the great problems to which it immediately relates, but to the whole range of chemical theory.

The use of the expression "atomic weight" implies the adoption of some form of atomic theory; but forty or more years ago Dalton's atomic theory was by many of the most philosophical chemists and physicists regarded as only a convenient hypothesis, which might be temporarily useful, but could not be accepted as representing physical reality. Since that time, however, a variety of circumstances have contributed to consolidate the Daltonian doctrine. The estimation of the ratios called atomic weights has been the subject of research, attended by more and more elaborate precautions to secure accuracy, from the time of Dalton himself onward through successive generations down to the present day. Though the atomic weights of the majority of the common elements are now known to a high degree of accuracy, the acknowledged errors have been sufficiently great to render abortive various attempts to reduce them to any common scheme of mathematical relationship. As is well known, the most important step toward the systematisation of atomic weights was taken about 1860, mainly on the grounds eloquently and convincingly set forth by Cannizzaro,[1] in consequence of which the arbitrary selection of numbers for atomic weights was superseded by the practical recognition of the law of Avogadro and the application of the law of Dulong and Petit, so that a common standard was established. No general scheme of atomic weights was previously possible, partial and imperfect efforts in this direction being represented by Dœbereiner's triads and the principle of homology made use of by Dumas. Only so soon as numbers representing the atomic weights of calcium, barium, lead, and other metals were corrected and brought into the same category as those of oxygen, sulphur, and carbon was there some chance of determining whether these numbers possessed a common factor or were capable of exhibiting mathematical inter-relations which might be regarded as symbolic of physical relations or even directly

[1] Prof. Walden, at the end of a biographical notice recently published in the *Berichte d. Deut. Chem. Ges.*, April, 1909, gives a list of 262 printed publications by Mendeléeff. These include, not only memoirs on physical and chemical subjects, but books, pamphlets, reports, and newspaper articles relating to exhibitions, to the industries of Russia, to weights and measures, to education, to art, and even to spiritualism.

[1] 1858, and later, Faraday Lecture, 1872.

dependent upon them. The first step in this direction was taken by J. A. R. Newlands, who, after some preliminary attempts in 1864–5, discovered that when the elements are placed in the order of the numerical value of their atomic weights, corrected as advised by Cannizzaro, the eighth element starting from any point on the list exhibits a revival of the characteristics of the first. This undoubtedly represents the first recognition of the principle of periodicity in the series of atomic weights, but whether discouraged by the cool reception of his "law of octaves" by the chemical world or from imperfect apprehension of the importance of this discovery, Newlands failed to follow up the inquiry. It was not long, however, before the matter was taken up by others, and doubtless the improvements in the estimation of atomic weights, following on the work of Stas, then only recently published, inspired greater confidence in the approximate accuracy of the numbers adopted as atomic weights, and thus encouraged inquiry into their relations. The subject is, indeed, an attractive one, for it involves considerations which lie at the foundations of all our notions respecting the physical constitution of matter, and accordingly we find papers by many chemists dealing with the question of these numerical relations. Odling especially seems to have given much thought to the subject, and, ignoring Newlands's previous attempts, he drew up towards the end of 1864[1] a table containing a list of all the then well-known elements, arranged horizontally in the order of their generally accepted groups, and perpendicularly in the order of their several atomic weights. He concludes an article in Watts's Dictionary a few months later with these words:—"Doubtless some of the arithmetical relations exemplified in the foregoing table are merely accidental, but, taken altogether, they are too numerous and decided not to depend on some *hitherto unrecognised* law." It is important to note the words I have italicised.

Such, then, was the state of knowledge about this time. Evidently the way was being prepared, but the prophet had not made his appearance—the seer who could look with the eyes of confidence beyond the clouds of uncertainty which obscured all ordinary vision.

In March, 1869, Mendeléeff communicated to the Russian Chemical Society an enunciation of the principle of periodicity and a statement of some of the consequences of this recognition of the relation of properties to atomic weight throughout the whole range of the known elements, and this statement was accompanied by a table which, while it bears a close resemblance to Odling's table of 1864, was apparently connected in his mind with an idea which became clearer and more decisive in the modifications which he immediately afterwards introduced into the arrangement.

Mendeléeff's First Table of the Elements.

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104·4	Pt = 197·4
			Fe = 56	Ru = 104·4	Ir = 193
			Ni = Co = 59	Pd = 106·6	Os = 199
H = 1			Cu = 63·4	Ag = 108	Hg = 200
	Be = 9·4	Mg = 24	Zn = 65·2	Cd = 112	
	B = 11	Al = 27·4	? = 68	U = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79·4	Te = 128?	
	F = 19	Cl = 35·5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85·4	Cs = 133	Tl = 204
		Ca = 40	Sr = 87·6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75·6	Th = 118		

From this arrangement, in which the elements are placed in vertical columns, according to increasing atomic weight, so that the horizontal lines contain analogous elements, again according to increasing atomic weight, Mendeléeff deduced the fundamental principle which he expressed as follows:—The elements arranged according to the magnitude of atomic weight show a periodic[2] change of properties.

[1] Quart. J. Sci., 1864, i, 643; and Watts's Dictionary, vol. iii, 975.

[2] Here an error in the German translation does an injustice to the original, inasmuch as the Russian word for periodic is rendered "stufenweise" (gradual).

Previous students of the subject had been, for the most part, struck with the relations obviously subsisting between the members of the several natural families of elements, but had, with few exceptions, failed to perceive that there must be a *general* law binding the whole together. However, Mendeléeff, with that noble sentiment of justice which always animates the truly scientific mind, admits that the idea of a general law had already been foreshadowed by others (Faraday lecture, 1889).

Mendeléeff's table of 1869 was subsequently in 1871 modified so as to assume the form with which we have all been so long familiar, and which is to be found in every modern text-book. Thus it may be claimed for Mendeléeff that he was actually the first, not only to formulate a general law connecting atomic weights with properties, but was the first to indicate its character, and, as himself ("Principles," 1905, ii., p. 28) has pointed out, he was the first "to foretell the *properties of undiscovered* elements, or to alter the accepted atomic weights" in confidence of its validity. The time was, in fact, ripe for the enunciation of this general principle, and, the suggestion once given, the relations embodied in the law could not fail to attract other chemists. Accordingly, in December, 1869, Lothar Meyer, with such knowledge of Mendeléeff's scheme as could be derived from the imperfect German version of his paper of the previous March, proved himself a convinced exponent of the idea by contributing to Liebig's *Annalen* a paper containing a table, substantially identical with that of Mendeléeff, and his famous diagram of atomic volumes, which, more clearly even than the tabular scheme, illustrates the principle of periodicity.

The history of science shows many instances of the same kind. Great generalisations have often resulted from the gradual accumulation of facts which, after remaining for a time isolated or confused, have been found to admit of coordination into a comprehensive scheme, and, this once clearly formulated, many workers are found ready to assist in its development. The case is nearly parallel to the recognition of the operation of natural selection by Darwin and Wallace, or it might be compared to the discovery of oxygen by Priestley and Scheele and the utilisation of this knowledge by Lavoisier. In each case much preparatory work had been done, and a body of knowledge had been gradually accumulated which, when duly marshalled and surveyed by the eye of a master, could scarcely fail to reveal to him the underlying principle. The full consequences, however, would appear only to a few.

I regard it as unnecessary, in the presence of the fellows of the Chemical Society, to review with any detail the multitudinous applications of the scheme of the elements constructed on the basis of the periodic law. These are the commonplaces of modern theoretical chemistry. They are embodied in every text-book of any importance, and are related by every lecturer and teacher as familiar and indisputably recognised consequences of the system. We may therefore pass lightly over the story of the prediction by Mendeléeff of the properties of undiscovered elements, confirmed so remarkably by the discovery of scandium, gallium, and germanium, and related in dramatic language by Mendeléeff himself (Faraday lecture). We may also pass over the applications of the system to the correction of atomic weights, illustrated by the case of beryllium, the recognition of previously unnoticed relations, and the discovery of new elements, notably the companions of argon (Ramsay, Presidential Address to Section B, British Association, 1897, and Proc. Roy. Soc., 1898, lxiii., 437).

It will be more profitable to consider a few of the difficulties which still encumber the application of the law, and which, while limiting our acceptance of it in an unqualified form as applicable to the whole of the elements, tempt the speculative mind to wander in wide fields of conjecture.

Can it be truly said that the elements arranged in the order of their atomic weights show without exception periodic changes of properties? This question has been propounded already, but has never been fully discussed, even by Mendeléeff. An examination of the facts seems, however, to indicate the possibility of some other principle,

which, while it does not supersede the periodic scheme, would, if it could be recognised, supplement it.

From a consideration of the almost unbroken sequence in the atomic weights of the known elements, it seems probable that few additional elements are to be expected, except possibly one following Mo and another following W, save in the region from Bi to Ra. This suggests the remark that, after all, it is not necessary to assume that the materials of which the earth consists should necessarily include a sample of every possible element indicated by such a scheme. Some which are missing from terrestrial matters may perhaps be responsible for phenomena recognisable by the spectroscope in stars or nebulæ far distant in cosmical space. The unexpected, however, often happens, and, remembering the discovery of terrestrial helium, it is permissible to hope that some of the vacant spaces may hereafter be filled by earthly occupants.

There is one important point to be noted here, namely, that if the so-called rare earth metals, praseodymium, neodymium, samarium, gadolinium, terbium, dysprosium, erbium, ytterbium, and others of which the existence is doubtful, do lie in the position indicated, the original statement of the periodic law breaks down at this point.

One result of the recognition of the periodic law is that theories concerning the genesis of the elements have received a stimulus previously unknown. It is, however, interesting to note the attitude of Mendeléeff toward this question, and the small extent to which this attitude appears to have become modified with the lapse of time. When, in 1889, twenty years after the discovery of the law, he composed the Faraday lecture, he seems to have regarded speculation in this direction as a kind of abuse of the periodic system.

Fifteen years later, after the discovery of the argon group of elements, of the phenomena of radio-activity, and of radium, it became necessary to consider the relations of these substances to the periodic scheme. In a remarkable article contributed to the new Russian Encyclopædia, and subsequently printed as Appendix iii. to the "Principles" (English edition, 1905), Mendeléeff gives a new table of the elements, in which places are found, not only for the argon group and radium, but for two hypothetical elements, which are placed before helium and designated x and y.

The y in the table is supposed to be an analogue of helium, and may be identified hereafter with "coronium," which has been recognised in the sun's coronal atmosphere. This gas would have, according to Mendeléeff, a density about 0·2, and therefore a molecular weight about 0·4, or about one-tenth that of helium.

x is the "ether" of the physicist, for which Mendeléeff, disregarding conventional views, supposes a molecular structure. He also assumes that, like the argon group, this element is chemically inert and possesses a very low density and atomic weight, estimated at 0·000,000,000,053.

Chemists and physicists have, however, found it impossible to resist the fascination of this problem, and accordingly there have been many hypotheses as to the origin of the elements and the nature of their connection with one another. These seem to be inseparable from the periodic scheme itself, which at once provokes the inquiry, Why do these numerical relations occur, and what is the meaning of them if they do not point to a common genesis or the operation of some process of evolution?

Hypotheses concerning the evolution of the elements have hitherto been usually based on the assumption that the successive stages of condensation of elemental matter proceeded from a single primary stuff, which by a process analogous to polymerisation among carbon compounds gave rise to atoms of greater and greater mass, which were stable at the prevailing and any lower temperature. The physical cause of the successive condensations is supposed to be a falling temperature. It is, of course, possible to imagine that if to the stuff of which hydrogen atoms consist are added successive portions of matter of the same kind, stable structures may at intervals result which we know as the atoms of the elements helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, and fluorine, provided the idea of internal structure in these atoms is allowed. Otherwise, from the mere accretion of matter upon a central nucleus, there seems no sufficient reason why there should not have been formed an indefinite number of intermediate masses corresponding to an indefinite number of what would be called elements. Further, it is difficult to understand why simple increase of mass should change, say, oxygen into fluorine, while a further addition of the same kind should change negative fluorine into inert neon or positive sodium. The possibility of the condensation of a single "protyl" so as to produce, at successive though unequal stages of cooling, the elements known to the chemist, has been most ably discussed long ago by Sir William Crookes.

This hypothesis, however, was put forward long before the work of Sir J. J. Thomson and his school was given to the world and the electron was accepted as a physical reality. The hypothesis that one elemental stuff may give rise to the whole array of known elements by a process of condensation accompanied by a loss or gain of electrons, the mass of which is approximately one-thousandth of the mass of an atom of hydrogen, forms the subject of a paper by Mr. A. C. G. Egerton in a recent number of our Transactions (1909, xcv., 239). The atomic weights calculated by his formula agree closely with the experimental atomic weights of the first fifteen elements, but the hypothesis gives no explanation of the facts observed in the physical properties of the elements arranged according to the Mendeléeff scheme, their alternation of odd and even valency, the transition from positive on one side of the table to negative on the other, the periodicity of properties shown by the sudden change of character in passing from fluorine to the next element, whether it be neon or sodium.

Another paper by Messrs. A. C. and A. E. Jessup (*Phil. Mag.*, 1908 [vi.], xv., 21) has recently provided a hypothesis of an entirely different character. From a study of the spectra of the nebulæ, these authors have been led to assume the existence of two hitherto unrecognised elements, to which the names protoglucinum and protoboron are assigned. These with hydrogen and helium are supposed to represent *four* initial substances, or protons, which, by condensation directly or indirectly, give rise to all the rest of the elements. The arguments of these authors are ingenious, but rather artificial in view of the fact that the number of groups in the periodic scheme to be provided for is greater than four.

In the Mendeléeff chart of the elements there is nothing more striking than the gathering of the negative elements toward what may be called the N.E., and the segregation of the positive elements toward the S.W., the centre of the intermediate territory being occupied by elements which play a more or less undecided part. I have elsewhere (Presidential Address, 1905, Trans., lxxxvii., 564) directed attention to the fact that carbon, at any rate, is not directly deposited by electrolysis from any of its compounds, with positive hydrogen on the one hand, or negative chlorine on the other. I believe the same is true of silicon, these two elements standing in a middle position between the extremes occupied by lithium and fluorine respectively.

If we assume that atoms are made up of two parts (protyls), positive and negative, in proportions which determine by the preponderance of one or the other whether the element shall exhibit the positive character of a metal like lithium or the negative character of a halogen, we arrive at a hypothesis which recalls the ideas put forward nearly a century ago by Berzelius. His views are familiar to every student of the history of chemistry, but have long been relegated to the lumber-room of worn-out doctrine. The last few years have, however, given us the remarkable experimental investigations of J. J. Thomson already referred to, and the new conceptions concerning the nature of atoms, which revive the fundamental idea that they are made up of two components.[1]

[1] Carnelley, in 1885 (Brit. Assoc. Reports), brought forward the idea "that the elements are not elements in the strict sense of the term, but are, in fact, compound radicals made up of at least two simple elements, A and B." The element A was supposed to be identical with carbon, while to B was assigned a negative weight, − 2, and it was suggested that it might be the ether of space. C. S. Palmer (Proc. Colorado Scient. Soc.) assumed the existence of two sub-elements, to which he gave the names "kalidium" and "oxidium," and his views appear to have a general resemblance to the hypothesis suggested in the text. The original article is abstracted in Venables's "Periodic Law," and is referred to in footnotes in Palmer's translation of Nernst's "Theoretical Chemistry."

Setting out the known elements in the order of the numerical value of their atomic weights, we find that between the first three elements, H=1, He=4, and Li=7, the difference, 3, is greater than would be expected by comparison with the differences noticed between the elements of greater atomic weight which immediately follow them. In order to satisfy the hypothesis just put forward, there appears to be wanting an element which should stand in the same relation to fluorine as hydrogen to lithium. This would have an atomic weight 2·7 approximately. Whether this exists, and whether its existence is indicated by the unappropriated spectral lines of nebulæ or corona, can only be a matter of conjecture. Mendeléeff, in his (1905) latest speculations concerning the possibility of still undiscovered elements, has suggested the existence of a new element of the halogen group with an atomic weight about 3;[1] but, as already sufficiently shown, he accepted no hypothesis which involved any idea of the composite nature of the elements. It would therefore have been foreign to his system to employ this element in any such manner.

The conceptions presented to us in J. J. Thomson's work permit of several supplementary hypotheses, especially the idea that if atoms are really made up of smaller corpuscles these are not thrown together in confusion, but, as he has shown, must be distributed within the mass in a definite order, which is determined by the attraction of the electro-positive shell and the self-repulsion of the negative corpuscles included in it. Once the idea of structure within the atom is admitted, the possibility presents itself of there being for the same mass more than one arrangement corresponding to what is called isomerism in compounds.

I have dwelt at some length on these various hypotheses, because the discussion of the subject to which they relate indicates, in my opinion, one of the consequences of the promulgation and general acceptance of the periodic scheme of the elements. This is, however, not the only result of the recognition of its validity and usefulness by chemists generally. That the elements stand in a definite relation to one another implies that their compounds also fall into their places in an orderly system, and consequently a basis is provided for the complete systematisation of the whole science of chemistry. There is scarcely a treatise on chemistry which does not bear evident witness to this influence; and this is perhaps not the least among the services rendered by this generalisation, for not only is the learner enabled to remember a much larger number of facts than previously, but he is led to perceive a connection between phenomena and processes which was almost entirely wanting so long as practical chemistry consisted mainly of a bundle of recipes. Here it is fitting that we should glance at the famous treatise by Mendeléeff himself, "The Principles of Chemistry," of which we possess three editions in English, the last of which, issued in 1905, is a rendering of the seventh edition (1903) of the original. An eighth Russian edition began to be issued in 1905, but is incomplete. To this remarkable book it is impossible to do justice in a brief notice or to communicate to those who have not read it an adequate impression. Clearly it is a work of genius, but such works are not always the most suitable for beginners, though for the advanced student nothing can be more inspiring. The "Principles" embody in reality two distinct treatises, for the text, which is written in an easy style, open to quite straightforward reading, is accompanied by notes which are often more voluminous and usurp entire pages. Even the preface is attended by these commentaries, which are all interesting as showing the spirit of the writer and the restless activity of his mind.

Little more remains to be said. In the seventeenth century Robert Boyle taught us how to distinguish elements from compounds, and how to give to the word "element" a definite connotation clearly distinguishing it from the elusive and fantastic language of the alchemists. In the eighteenth century Lavoisier showed the true nature of the most familiar of chemical compounds, namely, acids, bases, and salts, and helped to lay the foundation of quantitative chemistry. At the beginning of the nineteenth century Dalton gave to chemistry the atomic theory, of which it is not too much to say that it provided the scaffold by the aid of which the entire fabric of modern theoretical chemistry has been built up. Sixty years later this conception, developed and adorned by the labours of an army of earnest workers, has been shown to us in a brilliant new light thrown over the whole theory by Mendeléeff.

The views of Boyle, of Lavoisier, and of Dalton have been corrected by experience and broadened by extended knowledge, but the fundamental and essential parts of their ideas remain, and their names are immortal. In like manner the expression of the periodic law of the elements as known to the present generation is destined, we may believe, to be absorbed into a more comprehensive scheme by which obscurities and anomalies will be cleared away, the true relations of all the elements to one another revealed, and doubts as to the doctrine of evolution resolved in one sense or the other; but as with the atomic theory itself, there is no reason to doubt that the essential features of the periodic scheme will be clearly distinguished through all time, and in association with it the name of Mendeléeff will be for ever preserved among the fathers or founders of chemistry.

[1] It may also, perhaps, be worthy of note that Mr. Egerton's calculations (*loc. cit.*) lead him to postulate an element of nearly this atomic weight, namely, 2·9844, although his paper gives no indication as to its character.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. C. Forster Cooper has been appointed demonstrator of animal morphology by the professor of zoology and comparative anatomy for five years from Christmas, 1909.

Dr. Hobson has been appointed chairman of the examiners for the mathematical tripos, part ii. (new regulations), 1910.

The special board for physics and chemistry has appointed Mr. F. W. Dootson as assessor in chemistry to the examiners for the mechanical sciences tripos in 1910.

The Quick professor of biology commenced on February 2 six lectures on the pathogenic Protozoa, to be given on Wednesdays and Fridays. Attendance is free to members of the University. There will be two lectures on February 23 and 25 on "Recent Progress in the Treatment of Protozoal Diseases." These two lectures will be free to all desiring to attend.

The chairman of the board of anthropological studies gives notice that Mr. Roscoe's lectures on the natives of Uganda will be given on Tuesdays, at 5 p.m., in the archæological museum.

DURHAM.—The University this term comes under the operation of a new constitution established by an unopposed Act of Parliament last session. Originally the effective control of this University rested with the Dean and Chapter of Durham, who founded it, but gradually, after the incorporation of the Newcastle College of Medicine in 1852 and the establishment of the Durham College of Science, now Armstrong College, in Newcastle, actual power passed into the hands of an academic body, the Senate. This body, showing the anomalies of its growth, lately left much to be desired in representing a balance among the interests involved. Fortunately, the interests were not really competitive, and a solution has been found by consent. The Durham colleges retain their original endowments, and remain constituent colleges on the model of the old universities. A new Senate is established, elected in equal shares from Durham and Newcastle, which assigns the conditions for graduation, while each division is at liberty to propose for the approval of the Senate independent courses for the same degree. Thus the degree of B.A., which has hitherto been reserved to students from the Durham colleges, will now be open to students from Newcastle as soon as an approved course is established, and it is hoped that this will lead to a considerable development of Armstrong College upon the arts side, hitherto much stunted in comparison with its equipment for science. The first Vice-Chancellor, appointed on January 25, is Dr. F. B. Jevons, the well-known principal of Hatfield Hall, in Durham. It is much regretted that Sir Isambard Owen, to whose tact the success of the negotiations is largely due, is removed from participation in the first steps of the